

# Neuromuscular recovery in ACL reconstruction with Bone-Tendon-Patellar-Bone and Semitendinosus-Gracilis autograft

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**Summary.** *Objective:* Several different types of grafts have been used in ACL rupture. The purpose of the study was to compare the recovery of lower limbs muscle strength and proprioception in athletes, who underwent ACL reconstruction with Bone-Patellar-Tendon-Bone (BPTB) versus semitendinosus and gracilis (HS) autografts. *Methods:* We enrolled 30 male amateur athletes. Each patient was evaluated by isokinetic test, triaxial accelerometer test and balance test with stabilometric platform. Isokinetic test evaluated quadriceps and hamstrings Peak Torque. Accelerometer test evaluated squat jump test (SJT) and stiffness test (ST). The recording on the balance platform was performed with open and closed eyes and evaluated medio-lateral and anterior-posterior pathways. *Results:* 30 patients were selected (15 in group BPTB and 15 in group HS). In SJT we noticed a statistically significant difference in height of jump in the involved side in favour of Group BPTB ( $p=0.037$ ) and not significant difference in the other parameters. In the ST, we did not observe significant statistical differences in the parameters of the test. The stabilometric platform data and isokinetic peak torque parameters did not show a significant difference. *Discussion:* Little high quality researches are available to help determine when patients can safely return to full activity and sport. Included evaluation criteria were a combination of factors regarding knee motion, muscles strength and neuromuscular function. *Conclusion:* In our study, despite a not full recovery of explosive strength in HS group, the balance and the other parameters after one year are comparable between the two graft. In our findings there isn't clinical difference between the two grafts. We suggest that the evaluation of explosive strength and proprioception are the priority parameters in neuromuscular recovery after ACL reconstruction. ([www.actabiomedica.it](http://www.actabiomedica.it))

**Key words:** anterior cruciate ligament reconstruction, muscle strength, proprioception, postural balance

## Introduction

Anterior Cruciate ligament (ACL) rupture is one of the most common disabling and often painful knee injuries in sport (1). It usually requires surgery and it is associated with early osteoarthritis of the knee, regardless of the type of treatment (2). Several previously published studies report that the ACL injuries

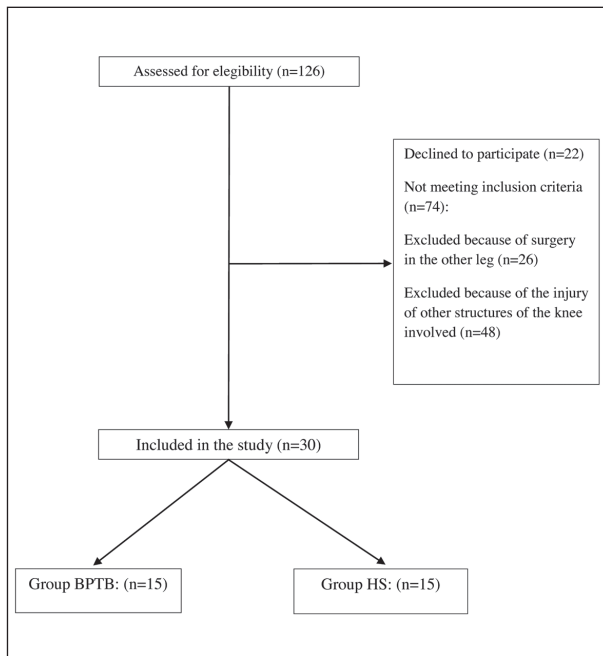
associated with sports are due primarily to non-contact mechanisms (3). ACL reconstruction is the most frequent treatment in athletes who intend to return to high-level sporting activities (4). There are several different types of grafts used for ACL reconstruction (5). One of these the bone-patellar tendon-bone (BPTB) autograft uses the central third of the patellar tendon. The BPTB autograft showed advantage

of having bone plugs on each end of the graft that provides excellent fixation points for the graft-screw interface and rapid healing within bone tunnel (6, 7). This method of reconstruction can, however, be associated with donor-site morbidity (8, 9), anterior knee pain, disturbances in knee sensitivity and kneeling discomfort (10, 11). Alternative graft choices have used semitendinosus and gracilis (HS) autograft (10), that reported advantages like decreased donor-site morbidity (12) and anterior knee pain (11, 13). Reported disadvantage associated with HS autografts include limitation in graft fixation, due to the absence of bone blocks on each end of the graft, leading to potentially less rigidity compared to a BPTB autograft (10). There is however insufficient evidence whether any of these treatments is superior in a long-term perspective for restoring knee function (14). Criteria of recovery after ACL reconstruction can include muscle strength, single-leg hop tests and proprioceptive recovery (15–18). Residual and persistent impairments are often as a limiting factor in return to preinjury levels of function and activity. In particular, quadriceps weakness is a primary impairment following ACL reconstruction and improvement of quadriceps strength is an important factor in functional outcome (15). Single-leg hop tests allow for a more comprehensive assessment of the functional capacity of the knee joint (19) and proprioceptive recovery of the knee joint contributes to sensation of right posture and joint stability. The recovery of knee stability depends on recovery of knee proprioceptive control with a specific rehabilitation program (20). Various assessment tools were traditionally used to quantify deficits in proprioceptive function after ACL injury and focused on measures of joint position sense or ability to detect the onset of passive motion (21, 22). Current practice around rehabilitation in ACL reconstruction is quite disparate and inconsistent due to the lack of clear sequential progression of functional exercises aimed at achieving specific goals. Furthermore, the current criteria for return to sport are both vague and rely on personal interpretation with the literature lacking of based criteria of muscular and proprioceptive recovery (23).

The purpose of this study was to evaluate neuromuscular recovery in athletes who underwent ACL reconstruction with BPTB and HS autografts.

## Materials and methods

126 amateur athletes were recruited; they underwent arthroscopic reconstruction bone-patellar tendon-bone autograft or semitendinosus and gracilis autograft after isolated anterior cruciate ligament rupture. We enrolled individuals that were treated with surgical intervention 12 months before and underwent the same rehabilitation program by same physiotherapist. The exclusion criteria in our study were females, patients with post-surgical complications, patients who underwent other interventions or injury at the other limb and individuals with past injury of other part of the limb involved or lesion of other structures of the knee injured. Participants were informed on the scope and procedures of the study. All individuals provided written informed consent before participating in the study. The Institutional Ethic Review Board of our University Hospital approved the study in accordance with the National Health Council Resolution No. 196/96 and with the Helsinki Declaration of 1975, as revised in 2000. Out of 126 participants subjected to the first evaluation, 22 refused to participate in the study, 74 were excluded for not meeting the inclusion criteria: 26 individuals were excluded from the study because of past surgery in the other leg and 48 because of the injury of other structures of the knee involved (Fig. 1). As a result, the study included 30 patients. In our series of cases, we divided the patients into 2 groups according to the graft type: 15 bone-patellar tendon-bone graft (Group BPTB), 15 semitendinosus-gracilis graft (Group HS). All patients were evaluated by isokinetic test (BIODEX Medical System®, Shirley, NY, USA) and by squat jump and stiffness test with triaxial accelerometer (Wiva® Let-Sense Castel Maggiore Bologna Italy). Isokinetic test was carried out with a precise number of operations in order to reproduce equal test conditions in all subjects. Before beginning the test, each subject did 5 minutes of warm-up and 5 repetitions to get familiar with the machine and prevent damages. The movements tested were knee flexion-extension with concentric-concentric contraction. Parameters tested were quadriceps and hamstrings Peak Torque (measured in Newton/meters). All patients performed an isokinetic strength test with 5 repetitions at an angular speed of 90°/s and



**Figure 1.** Flow Chart

an isokinetic endurance test with 15 repetitions at an angular speed of  $180^\circ/\text{s}$ . Patients observed 3 minutes of rest between the two tests. The flexion-extension test was performed with the patient sitting aligning the axis of rotation of the dynamometer with the knee one. Accelerometer tests were executed after 5 minutes by the isokinetic test, applying a neoprene belt in contact with the skin at the level of fifth lumbar vertebra (Fig. 2). All tests were carried out with a single leg testing injured limb. Between the two jump tests there was 3 minutes rest. Squat jump test (SJT) was executed with a single maximal jump, starting position at  $45^\circ$  of knee flexion, landing in vertical position and evaluating height of jump, time of flight, maximum speed, maximum power, maximum force and concentric work.

Stiffness test (ST) was executed with counter-movement jump followed by seven jumps at extended knee and landing after the seventh jump controlling the vertical position without doing further hops. The parameters tested with ST were: maximum height, average height, average time of flight, power of the best jump, average power and average stiffness. Moreover patients were tested with a balance test on stabilometric platform (Tecnobody Prokin, Dalmine (BG) Italy).



**Figure 2.** Accelerometer test

Each patient was asked before getting on the platform to take off shoes and socks. The recording was performed for a time of 30 seconds bare-foot on the stabilometric platform with arms at their sides and at the beginning with opened eyes staring a point and then with closed eyes (Fig. 3). SPSS 20.0 software was used for all analyses. Descriptive statistics of data included mean, standard deviations, standard error of mean, median, interquartile range, min, max and range. We analyzed the difference between the two grafts using the comparison of independent samples (Mann-Whitney test) analysis for analysis of involved knee data. P values of less than 0.05 were considered significant.



**Figure 3.** Balance test

## Results

The demographic characteristics of 30 patients are shown in Table 1. The values of isokinetic tests were normalized between dominant and non-dominant leg. We noticed in squat jump test a statistically significant difference in height of jump in favor of Group BPTB ( $p=0.037$ ) and not significant difference in the other parameters. In the Stiffness test, we didn't observe significant statistical differences in tested parameters. The

stabilometric platform results showed no significant difference and also there weren't statistically significant differences in all isokinetic parameters between the two groups. All data compared between the two groups are shown in the Table 2 (a-d).

## Discussion

Not many high quality researches are available to help determine when patients can safely return to full activity and sport (23). A premature return increases the risk for re-injury and graft failure.

A systematic review of over 264 studies addressing return to play after ACL reconstruction identified only 35 studies with objectives criteria for returning to sport activity (24). Some of these articles include a combination of factors such as knee motion, strength of supporting muscles, and neuromuscular function but in many of these studies time from surgery was the only factor taken into account. So clinicians typically use clinical and non-objective tests to determine whether patients can return to sports (15). Additional research is required to identify the most useful criteria for determining when an athlete is ready to return to sport with minimal risk of re-injury or graft failure. For selected athletes eager to return to competition, early participation may not be disadvantageous, provided an appropriate and rigorous rehabilitation program is followed (25). Some patients following reconstructive surgery of LCA are now returning to full activity at six months and some high-level athletes sooner. However studies supporting early participation involve small numbers of patients and athletes should be aware that this approach entails some risk of re-injury (26). Furthermore less than half of athletes who undergo LCA

**Table 1.** Demographic characteristics

Group	Characteristics	Mean	Median	Standard Deviations	Interquartile range
Group BPTB 15 Subjects	Age	26	23.00	8.01	19-34.25
	Body Mass Index	23.28	24.30	2.11	21.75-24.50
Group HS 15 subjects	Age	30.33	32.00	7.79	23.25-37.25
	Body Mass Index	23.01	23.70	2.08	21.55-24.65



**Table 2.** Test Data Comparison of independent samples (Mann-Whitney test)

Variables	Group BPTB		Group HS		p-value
	Median	Average Rank	Median	Average Rank	
<b>Squat Jump Test</b>					
Maximum Height (m)	.25	18.83	.22	12.17	.037
Time of flight (s)	.36	18.43	.33	12.57	.067
Maximum Speed (m/s)	1.64	17.77	1.57	13.23	.158
Maximum Force (N)	11.11	15.73	11.88	15.27	.885
Maximum Power (W)	13.22	16.53	11.99	14.47	.520
<b>Stiffness Test</b>					
Maximum Height (m)	.14	13.10	.16	17.90	.132
Average Height (m)	.12	14.40	.15	16.60	.492
Average Time of Flight (s)	.23	14.03	.27	16.97	.361
Average Contact time (s)	.31	14.10	.33	16.90	.383
Average Power (W)	10.24	13.27	12.27	17.73	.165
Power of the best jump (W)	12.54	13.67	13.70	17.33	.254
<b>Isokinetic Test</b>					
Peak_Torque extension 90°/s (N/m)	141.30	15.70	138.60	15.30	
.901Peak_Torque extension 180°/s (N/m)	103.20	15.13	102.50	15.87	.820
Peak_Torque flexion 90°/s (N/m)	88.30	14.97	88.30	16.03	.740
Peak_Torque flexion 180°/s (N/m)	68.30	15.73	70.60	15.27	.885
<b>Platform data</b>					
Path of Center Of Mass (Y) Open Eyes (Cm)	31.59	13.80	33.06	17.20	.290
Oscillation Medio-Lateral Open Eyes (mm)	72.09	13.20	82.19	17.80	.152
Oscillation Anterior-Posterior Open Eyes (mm)	94.75	14.53	102.60	16.47	.548
Path of Center Of Mass (Y) Closed Eyes (Cm)	37.62	16.87	34.56	14.13	.395
Oscillation Medio-Lateral Closed Eyes (mm)	86.72	14.53	97.93	16.47	.548
Oscillation Anterior-Posterior Closed Eyes (mm)	137.60	14.17	160.20	16.83	.407

reconstruction are able to return to sport within the first year after surgery (27). All over the years, several tests have been conceived in order to evaluate the effectiveness of two different types of grafts on patients that underwent to surgical ACL reconstruction. For example evaluating knee function including concentric as well as eccentric strength. Several trials have established that insufficient quadriceps strength may yield inferior performance in activities that require eccentric muscle action such as stair descent (28). The single-legged squat is a common clinical test that is part of rehabilitation of muscular skeletal injuries, including ACL reconstruction. The single-legged squat is pervasive during rehabilitation because it requires controlled motion that simulates common athletic positions and activities of daily living (29). This test is subjective, as

many other ones reported in literature. Unfortunately, there are a few references about objective tests that could lead to a solid evaluation of surgical methods effectiveness. Clinical data obtained with subjective tests are not sufficient to establish if it is possible to allow patient to return to sport activities. Furthermore the currently available evidence from randomized trials comparing patellar tendon and hamstring tendon reconstructions of ACL deficient knees provides an insufficient basis for drawing strong clinical recommendations with respect to the choice between these two grafts (14). The combined use of objective physical examination and clinical evaluation could allow clinicians to analyze the functional deficits of operated leg before sports return. Time-based rehabilitation alone is useless and it's necessary to find assessment tools

that will consider the progressive restoration of function (30). Our results showed a statistical significant difference in explosive strength in favour of Group BPTB in accordance with our previous article where we demonstrated that the explosive strength recovery and the other strength parameters are to take in account in ACL recovery evaluation (33). Two recent meta-analysis (31-32) affirm that the BPTB autograft might be superior in some physical tasks or about the failure rate but all of these reviews consider both graft types viable options for primary ACL reconstruction given that there was insufficient evidence to identify which of the two types of grafts was significantly better for ACL reconstruction as we have showed in this study.

## Conclusions

In our study the statistical difference in SJ data about maximum high of jump in favor of group BPTB could signify that the recovery of explosive strength is better in the BPTB reconstruction but the evaluation of a single parameters of SJ data could be not sufficient to understand if a kind of graft is better or could depend by different basal muscle strength. Moreover we did not find a significative difference in the stabilometric data, probably because the recovery of neuromuscular impairment leads to a good recovery of the other variables, indeed the absence of differences in Isokinetic data and ST results let us to consider that the recovery of strength and muscular elasticity was complete in both groups. We noticed that there is not clinical difference between the two grafts and we believe that the priority parameters for optimal neuromuscular recovery after ACL reconstruction are strength and proprioception recovery.

The present study presents several limitations that should be acknowledged. It included a small number of participants; several surgeons; no evaluation between two limbs and early follow-up is performed.

Future studies should include a large sample size, evaluation of patients operated by same surgeon and long term follow-up to better define objective parameters for complete recovery after ACL reconstruction.

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